Analysis of CO_2 and CH_4 Emission from Domestic Waste in Open Space Bendan Dhuwur Campus UPGRIS Semarang

Velma Nindita[1], Kurnia Widiastuti[2], Slamet Supriyadi[3]

[1,2,3] Faculty of Engineering and Informatics, Universitas PGRI, Jl. Sidodadi TImur No. 24 Semarang 50232, Central Java, Indonesia.

email : velma_nindita@yahoo.com

Abstract. Various activities especially in fulfillment daily needs, generate a lot of waste. One of the negative effects of waste generation is the contribution of greenhouse gas emissions to the atmosphere which causes global warming. Every location has waste, both organic and non-organic, or other types. The open space in Bendan Dhuwur campus area is dominated by organic waste due to leaf fall from many trees around. This is a concern because there is no proper waste management and it is immediately burned. This study focuses on analyzing the composition of waste and calculating the contribution of CO2 emissions from domestic waste generation at Bendan dhuwur campus of UPGRIS Semarang. The method used is random sampling accompanied by quantitative descriptive measurements and analysis. The result of the research shows that the calculation of waste composition for leaf waste is 3.58 x 10-3 Gg/year; twig waste 3.6 x 10-4 Gg/year; paper waste 3.57 x 10-4 Gg/year; plastic waste 2.02 x 10-4 Gg/year and CO2 emissions = 2.12 x 10-3 Gg/year; CH4= 2.57 x 10-5 Gg/year (leaves), CO2 = 2.18 x 10-4 Gg/year; CH4=2.58 x 10-6 Gg/year (twig), CO2 = 1.53 x 10-4 Gg/year; CH4= 2.56 x 10-6 Gg/year (paper), CO2 = 0.02 Gg/year; CH4= 1.45 x 10-6 Gg/year (plastic)

Keywords: waste, CO_2, CH_4

1. Introduction

Emissions from gases that cause warming the planet will be the highest record this year. The report was released in conjunction with a meeting of UN negotiators in Poland for the final round of talks on tackling climate change. Emissions are projected to increase by 2.7 percent this year, according to three studies released Wednesday from the Global Carbon Project, which track greenhouse gas emissions. This increase continues the increase of 1.6 percent last year. However, emissions are relatively stable in the previous three years. For the case in Indonesia, the increase in greenhouse gas emissions occurs because of the influence of all human activities, whether consciously or not, especially in the field of transportation and the amount of waste. This shows that the various activities carried out will have an impact on environmental conditions. The impact is none other than the production of several types of main gases called greenhouse gases

Total population in an area greatly affects the amount of waste produced. Various activities, especially in accordance to daily needs, generate a lot of waste. This is a concern for us as citizens of the community so that we can try to reduce of waste by each individual. One of the negative effects of waste generation is the contribution of greenhouse gas emissions to the atmosphere which causes global warming.

Urban waste management generally runs a collection and transportation system and is highly dependent on management at the final processing site (TPA). Not all landfills do waste processing properly, especially most regions in Indonesia still adhere to the open dumping system, so that the longer the landfill, the larger the landfill will be processing load. GHG emissions in Central Java amount to 30,432.36 gigatonnes of CO2 equivalent. Then in 2018, it increased by more than 100%, which was recorded at 74,673.24 gigatonnes of CO2 equivalent. The biggest contributor to GHG emissions in Central Java is the energy sector. The energy sector contributes to GHG reaching 54,689 gigatonnes of CO2 equivalent or about 73.24%. Then, followed by the agricultural sector, which is 24,356 gigatonnes of CO2 equivalent or 32.62%. The Central Java government based on the Regional Action Plan (RAD), until the end of 2020 has a target of reducing the rate of GHG emissions by 12.64% in accordance with Governor Regulation (Pergub) Number 43 of 2018 concerning RAD for GHG reduction.

Bendan Dhuwur Universitas PGRI Semarang is a campus that is used for laboratory activities of the Engineering faculty. There is domestic waste, especially organic type of waste that comes from the ruins of tree leaves, and the rest comes from human activities. This research was conducted by calculating the estimated emission of greenhouse gases (CO2 and CH4) from the composition of the waste by calculating the emission factor from the IPCC 2006 [1].

2. THEORY

Greenhouse Gases

The gases classified as GHGs are carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), and sulfurhexachloride (SF6). The six GHGs are gases based on the Kyoto Protocol which are considered responsible for increasing global warming. These gases have global warming potential which is calculated in CO2 potential or known as Global Warming Potential (GWP). GWP is the magnitude of the radioactive effect of GHGs when compared to CO2. GWP shows how many tons of CO2 are equivalent to one ton of other GHGs. Methane (CH4) has a GWP of 21 times CO2, while the GWP values for N2O, HFC, PFC and SF6 are 310, 140-11,700, 6500-9,200, and 23,900 times CO2, respectively.

Dinitrogen oxide (N_2O) has an average concentration that continues to increase from 1978 to 2010 at 0.2 to 0.3% annually. Activities that support the increase in the concentration of nitrous oxide in the atmosphere include soil fertilization, land use, biomass burning, and burning fossil fuels [2].

The greenhouse effect is the heat effect caused by the absorption of long-wave radiation from the sun by greenhouse gases in the lower atmosphere layer close to the earth's surface. The greenhouse effect is needed by the earth under normal conditions to maintain the balance of the earth's temperature. This means that with the greenhouse effect, the average temperature of the earth's surface that is not exposed to sunlight is not too low [3].

Emission Factor

The emission factor is used to calculate GHG emissions, where later the emission factor will be multiplied by the amount of fuel used so that the total amount of emissions released will be obtained. The equation for calculating the carbon footprint is as follows: Emissions = DA x

FE where DA is the data from the activity under study and FE is the emission factor from the activity under study. According to the Regulation of the President of the Republic of Indonesia No. 71 of 2011, Emission factor is the amount of GHG emissions released into the atmosphere per unit of certain activity.

Emission factors are determined based on research and are very specific to each ingredient or product. Since there is no specific emission factor for Indonesia, the emission factor determined by the IPCC is used.

Waste Composition

The composition of waste is a description of each component contained in the waste and its distribution. This data is important for evaluating the required equipment, systems, waste management and waste management plans of a city. The most frequent grouping of waste is based on its composition, for example expressed as % by weight or % by volume of paper, wood, leather, rubber, plastic, metal, glass, cloth, food, and other waste [4].The composition of waste is influenced by the following factors [5]

a. Collection frequency. The more often the garbage is collected, the taller the pile of garbage is formed. Paper waste and other dry waste will continue to increase, but organic waste will decrease due to decomposition.

b. Season. The type of litter will be determined by the ongoing fruit season.

c. Economic Conditions. Different economic conditions produce waste with different components. The higher the economic level of a society, the production of dry waste such as paper, plastic, and cans tends to be high, while the food waste is lower. This is due to the lifestyle of the high economic community which is more practical and clean.

d. Weather. In areas where the water content is quite high, the humidity of the waste will also be quite high.

e. Product packaging. Product packaging for daily necessities will also affect the composition of the waste. Developed countries such as America, Germany, French and others use paper a lot as packaging, while developing countries such as Indonesia, India, and others use a lot of plastic as packaging.

3. Methods

A. Calculate the Percentage of Composition

The composition of the waste can be calculated using the formula:

$$\% \text{ composition} = (\prod \text{component weight/total sample weight})\text{x}100\%$$

B. Calculation of GHG Emissions

The calculation of BAU GHG emissions uses a reference from Bappenas, namely the Technical Guidelines for Calculation of Baseline GHG Emissions in the Waste Sector which adopts the IPCC calculation standard [5] in the form of an excel calculator. BAU calculation to determine the amount of GHG emissions produced without any mitigation/emission reduction activities. The 2006 IPCC calculation model has been used in many developing countries. The potential GHG emission from burning waste is N2O.

1. Calculation of N2O Emissions

N2O = (IWi*EFI)/10-6 (1)

IWi : Amount of waste burned (Gg/year)

EFi : N2O emission fraction, which is 150 g/ton (dry weight) for open combustion

10-6 : kg to Gg konversi conversion factor

2. Carbon Content Fraction (CF Symbol) and Carbon Fossil Fraction (FCF Symbol) Carbon content fraction is the value of carbon content and fossil carbon fraction obtained based on the composition of the burned waste, and to calculate the carbon content value the following equation can be used.

4. Results And Discussion

Bendan Dhuwur Universitas PGRI Semarang is a campus that is intended for laboratory activities for students of the Faculty of Engineering and Biology Education. This campus has an area of approximately 2200 m2. The number of students, lecturers, and employees consisted of ± 250 students of Mechanical Engineering, ± 80 of Civil Engineering, ± 80 of Electrical Engineering, ± 40 of Food Technology, 30 lecturers, 2 employees, and 5 cleaners. Garbage in Campus 3 is not fully implemented by the concept of waste management, both 3R and others. Garbage is only collected in the pine tree yard and immediately burned without any further processing.

4.1 Waste Weight Calculation based on Composition

To determine the characteristics of the composition of waste on campus 3, measurements and sampling were carried out with reference to SNI_19-2454-2002. Waste samples that have been taken, weighed and measured volume using a measuring tub that has been prepared. Based on the results of the calculation analysis that the amount of waste generated on campus 3 of PGRI University Semarang for 8 consecutive days within 3 months in an interval per month starting from July-September 2019, then averaged to become one data for 8 days in 3 months, then the results of the calculation of the most waste are leaf category waste as much as 88%, twig waste composition 4.5%, paper waste 4.45%, and plastic waste 2 ,51%.

Calculation of waste composition

i. % leaf waste composition $= \dfrac{\prod \text{component weight (kg)}}{\prod \text{waste total (kg)}} \times 100\%$

(8 hari)

$= \dfrac{44,5}{55,96} \times 100\%$

$= 79,52$ kg

% year $= 298,20$ kg x 12 bulan

$= 3578,45$ kg/th

ii. **%** twigs composition $= \dfrac{\prod \text{component weight (kg)}}{\prod \text{waste total (kg)}} \times 100\%$

(8 hari)

$= \dfrac{4,5}{55,96} \times 100\%$

$= 8,04$ kg

% year $= 30$ kg x 12 bulan

$= 360$ kg/th

iii. **%** paper waste composition = $\frac{\prod \text{component weight (kg)}}{\prod \text{waste total (kg)}}$ x 100%

(8 hari)

= $\frac{4,45}{55,96}$ x 100%

= 7,95 kg

% tahun = 29,82 kg x 12 bulan

= 357,8 kg/th

iv. % plastic waste composition = $\frac{\prod \text{component weight (kg)}}{\prod \text{waste total (kg)}}$ x 100%

(8 hari)

= $\frac{2,51}{55,96}$ x 100%

= 4,49 kg

% year = 16,82 kg x 12 bulan

= 201,84 kg/th

Calculation of Greenhouse Gases Potential (CO_2 and CH_4) based on GHG Technical Guidelines for Waste Sector Management (BAPPENAS,2014)

1. **Leaf Waste**

a. CO_2 Emission calculation

CO_2 = $SW_i * dm_i * CF_i * FCF_i * Of_i * 44/12$

SWi : total burned waste (Gg/tahun)
Dmi : dry weight fruction of burned waste
CFi : dry weight carbon content fruction
FCFi : total carbon fossil fruction
OFi : Oxidation factor, 58% for open burning
44/12 : Converted from C to CO_2

CO_2 = $3,58x10^{-3} * 0,57 * 0,49 * 0,58 *3,66$

CO_2 = $2,12x10^{-3}$ Gg/tahun

b. CH_4 Emission calculation

CH_4 = $\sum(IWi*EFi)/10^{-6}$

IWi : total burned waste (Gg/tahun)
EFi : CH_4 Emission fruction (6500g/ton (dry weight) for open burning
6500 gr/ton converted Gg $7,16x10^{-3}$
1 ton : 0,000907 Gg
1gr : 1x10-9 Gg
10^{-6} : Converted from kg ke Gg

CH_4 = $3,58x10^{-3} * 7,16x10^{-3}$
CH_4 = $2,57x10^{-5}$ Gg/tahun

2. Twig

a. CO_2 Emission calculation

CO_2 = SWi * dmi * CFi * FCFi * Ofi * 44/12

SWi : total burned waste (Gg/tahun)
Dmi : dry weight fruction of burned waste
CFi : dry weight carbon content fruction
FCFi : total carbon fossil fruction
OFi : Oxidation factor, 58% for open burning
44/12 : Converted from C to CO_2

CO_2 = $3,6x10^{-4} * 0,57 * 0,5 * 0,58 *3,66$
CO_2 = $2,18x10^{-4}$ Gg/tahun

b. CH_4 Emission calculation

CH_4 = $\sum(IWi*EFi)/10^{-6}$
IWi : total burned waste (Gg/tahun)
EFi : CH_4 Emission fruction (6500g/ton (dry weight) for open burning
6500 gr/ton converted Gg $7,16x10^{-3}$
1 ton : 0,000907 Gg
1gr : 1x10-9 Gg
10^{-6} : Converted from kg ke Gg

CH_4 = $3,6x10^{-4} * 7,16x10^{-3}$
CH_4 = $2,58x10^{-6}$ Gg/tahun

3. Paper

a. CO_2 Emission calculation
CO_2 = SWi * dmi * CFi * FCFi * Ofi * 44/12
SWi : total burned waste (Gg/tahun)
Dmi : dry weight fruction of burned waste
CFi : dry weight carbon content fruction
FCFi : total carbon fossil fruction
OFi : Oxidation factor, 58% for open burning
44/12 : Converted from C to CO_2

CO_2 = $3,57x10^{-4} * 0,44 * 0,46 * 1 * 0,58 *3,66$
CO_2 = $1,53x10^{-4}$ Gg/tahun

b. CH_4 Emission calculation

CH_4 = $\sum(IWi*EFi)/10^{-6}$

IWi : total burned waste (Gg/tahun)
EFi : CH_4 Emission fruction (6500g/ton (dry weight) for open burning
6500 gr/ton converted Gg $7,16x10^{-3}$
1 ton : 0,000907 Gg
1gr : 1x10-9 Gg
10^{-6} : Converted from kg ke Gg

CH_4 = $3,57x10^{-4} * 7,16x10^{-3}$
CH_4 = $2,56x10^{-6}$ Gg/tahun

4. Plastic waste

a. CO_2 Emission calculation

CO_2 = $SW_i * dm_i * CF_i * FCF_i * Of_i * 44/12$

SWi : total burned waste (Gg/tahun)
Dmi : dry weight fruction of burned waste
CFi : dry weight carbon content fruction
FCFi : total carbon fossil fruction
OFi : Oxidation factor, 58% for open burning
44/12 : Converted from C to CO_2

CO_2 = $2,02x10^{-4} * 0,57 * 0,75 * 100 * 0,58 *3,66$
CO_2 = 0,02 Gg/tahun

b. CH_4 Emission calculation

CH_4 = $\sum(IWi*EFi)/10^{-6}$
IWi : total burned waste (Gg/tahun)
EFi : CH_4 Emission fruction (6500g/ton (dry weight) for open burning
6500 gr/ton converted Gg $7,16x10^{-3}$
1 ton : 0,000907 Gg
1gr : 1x10-9 Gg
10^{-6} : Converted from kg ke Gg

CH_4 = $2,02x10^{-4} * 7,16x10^{-3}$

From the calculation results, it can be seen that CO_2 and CH_4 emissions produces from leaf, twig, paper, and plastic no treatment processing at all. Leaf waste should be processed through the composting and not suggest to directly burned in open burning. The twig waste is bigger emission because the amount of waste also much. The twig can be mixed for composting with the enumeration process. We have to minimize paper and plastic waste, because it can be processed with 3R.

5. Conclusion and Suggestion

Conclusion:
1. Composition of waste for leaf waste 3.58 x 10-3 Gg/year; twig waste 3.6 x 10-4 Gg/year; paper waste 3.57 x 10-4 Gg/year; plastic waste 2.02 x 10-4 Gg/year.
2. Leaf litter:

Estimated CO_2 emission CO_2 2,12 x 10^{-3} Gg/year, while the CH4 emission is 2,57 x 10^{-5} Gg/year
twig waste:
Estimated CO_2 emission CO_2 2,18 x 10^{-4} Gg/year, while the CH4 emission is 2,58 x 10^{-6} Gg/year
Paper waste:
Estimated CO_2 emission CO_2 1,53 x 10^{-4} Gg/year, while the CH4 emission is 2,56 x 10^{-6} Gg/year
Plastic waste :
Estimated CO_2 emission CO_2 0,02 Gg/year, while the CH4 emission is 1,45 x 10^{-6} Gg/year
3. On average, 98% of the total waste on campus Universitas PGRI Semarang is organic, but the 3R process has not been carried out.

Suggestion

It is recommended that the process of separating waste from its source continuelly be carried out in order to facilitate the process of sorting waste for further processing of waste and measuring waste generation and waste composition continuously.

REFERENCES

[1] IPCC 2006 Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Tokyo: IGES.

[2] Artadi, F (2013) Studi Jejak Karbon dari Aktivitas di Kampus Fakultas Teknik Universitas Indonesia. Depok: UI Press

[3] Kementerian Lingkungan Hidup (2012) Pedoman Penyelenggaraan Inventarisasi Gas Rumah Kaca Nasional. Buku II – Volume 1 Metodologi Perhitungan Tingkat Emisi Gas Rumah Kaca Kegiatan Pengadaan dan Penggunaan Energi. Jakarta

[4] Damanhuri dan Padmi, (2004).Diktat Pengelolaan Sampah. Teknik Lingkungan Institut Teknologi Bandung (ITB): Bandung.

[5] Tchobanoglous, G, Theisen, H, Vigil, S, 1993. Integrated Solid Waste Management. Singapore: Mc Graw-Hill Book Co.

[6] Bappenas. 2014. Pedoman Teknis Perhitungan Baseline Emisi Gas Rumah Kaca Sektor Pengelolaan Limbah. Badan Perencanaan Pembangunan Nasional (BAPPENAS) Deputi Bidang Sumber Daya Alam dan Lingkungan Hidup. Jakarta.